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SHOT PEENING AS A METHOD FOR INCREASING FATIGUE STRENGTH OF GEARS HARDENED BY INDUCTION

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Fatigue failure of metal is one of the chief causes for the breaking of gear teeth working under conditions of reversed bending. Fatigue cracks are generally formed at the surface of the metal, and therefore particularly high requirements must be applied to the mechanical properties and microstructure of the surface layer.

Insignificant hardening cracks, residual tensile stresses, and ferrite network at the surface may start fatigue failure. Shot peening is effective as a surface treatment for improving resistance to fatigue.

Rear-axle involute gears of the S-4 self-propelling combine have been tested. These gears are made of 40 Kh chromium steel, being quenched after heating by high-frequency current. Tooth module of gears -- m, 5; tooth length, 45 mm; number of teeth, 42.

Gears were taken from production of the Sormovo and Lyubertsy plants and differed by variations in their heat treatment: gears from the Sormovo plant were quenched in water, and those of the Lyubertsy plant, in an emulsion. After quenching all gears were tempered at 200°.

Gears from the Sormovo plant were made of steel of the following chemical composition: 0.44% C, 0.55% Mn, 1.28% Cr, 0.12% Si, 0.023% S, 0.013% P. The composition of the steel for gears made at the Lyubertsy plant was as follows: 0.43% C, 0.62% Mn, 1.28% Cr, 0.22% Si, 0.025% S, 0.022% P. Hardness of Sormovo plant gears was 52-45 R_c in the hardened zone and 23 R_c in the core. Hardness of gears made at the Lyubertsy plant was 52-47 R_c and 24 R_c respectively.

Both batches of gears had unhardened tooth spaces. The hardened layer of the Lyubertsy plant gears was somewhat thicker but still did not extend to spaces between teeth. The microstructure of the hardened zone represented fine-needle martensite, and that of the core was comprised of fine-lamellar pearlite and ferrite, the latter having a banding tendency in the

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gears from the Lyubertsy plant. Shot peening operations were performed in a centrifugal installation of the VISKhOM (All-Union Institute of Agricultural Machine Building) with a rotary table. The cast-iron shot used for peening had a diameter of 0.5-1 mm. The centrifugal wheel rotated at 2,400 rpm.

On the basis of industrial experience, and results obtained by measuring deflections of the control plates, shot treatment for 15 min was found adequate with a distance of 300 mm from the outer rim of the centrifugal wheel to the surface under treatment. The deflection of the control plate, 1.25 mm thick, amounted to 0.45 mm.

Fatigue tests of gear teeth were conducted on a universal hydraulic machine of the Lozenghauzen type with power capacity of 35/17.5 tons. A special device, developed by R. S. Nikolayev and L. M. Shkol'nik (Zavodskaya Laboratoriya, No 10, 1949) was used. This device permitted simultaneous testing of two similar gears.

Teeth of gears were submitted to bending by pulsating load at speed of 1,000 cycles per min. The number of cycles for determining the endurance limit was 5 million. Reverse bending of teeth was created because of gradual change of load from a minimum value to maximum and inversely. The minimum loading was a constant one-ton load, causing 5.06 kg/sq mm stress in a tooth. The maximum load was different in every case. The first pair of teeth was loaded with 16 tons, almost the limit capacity of the pulsator, and failure occurred after 6,500 cycles. This created the possibility for selection of further loads which were decreased for every successive pair of teeth. Tests were not carried to actual fracture. Failure was determined by the moment of the appearance of a crack. Fatigue cracks usually began to develop in the unhardened zone, and failure occurred at the base of a tooth.

It was found that the fatigue limit of the teeth of gears made by the Lyubertsy plant amounted to 22.8 kg/sq mm at a load of 2,250 kg. After shot peening, the fatigue limit of these gears increased to 27.8 kg/sq mm, i.e., an increase of 22%, which corresponded to a load of 2,750 kg. Teeth of gears manufactured by the Sormovo plant had a fatigue limit of 20.3 kg/sq mm at a load of 2,000 kg.

The load on gears here investigated amounts to 1,200 kg under normal operational conditions, but increases to 4,800 kg during slipping. This factor, being compared with the results of testing, explains the causes of gear-teeth failures, especially in cases of unskillful driving of a combine.

This investigation permits the conclusion that the high-frequency induction-hardening technique employed at present by many plants, does not provide for the high fatigue limit and durability required of gears subjected to dynamic loads.

The life of gear teeth, treated by shot peening, increases 2.5 times, as compared with untreated gears, under a load of 3 tons, i.e., at stresses near the fatigue limit of these teeth. Under higher loads the increase in the life of teeth was not affected by shot peening.

The insufficient strength of gears made of 40 Kh chromium steel and hardened by high-frequency induction, makes necessary the investigation of gears made of other steels with application of cementation.

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